WIND ENERGY FACILITY WITH A CLOSED COOLING CIRCUIT

BACKGROUND OF THE INVENTION

The conversion of energy regularly results in energy being lost in the form of heat. This applies to both the conversion of the kinetic energy of wind into electrical energy in the generator of a wind energy facility, where these losses regularly occur in the main driving line of the wind energy facility, and also for the electrical feeding of energy generated by the wind energy facility into a medium voltage network. For this purpose, regular devices of power electronics, *e.g.*, rectifiers, and/or transformers, are necessary. In the main driving line, which is mounted in the nacelle for a wind energy facility, the losses occur overwhelmingly in the gears, at the bearings, and in the generator or at other control units, such as, *e.g.*, in the hydraulic systems or similar control and regulation units, which adjust the rotor blades or turn the wind energy facility into the wind. For gearless wind energy facilities, *e.g.*, model E-66 of Enercon, the main losses occur at the main driving line in the generator, *i.e.*, in the nacelle (head) of the wind energy facility.

For the power supply, losses occur overwhelmingly at the power transformer and, if necessary, in the power electronics, *e.g.*, in the rectifier.

For a 1.5 MW wind energy facility, the losses can be in the range of 60-100 kW. Up until now, these losses were dissipated into the environment by means of fans. In this way, cold air is suctioned in from the outside by the fans to cool the corresponding components, *e.g.*, the generator. The heated air is then blown back outside.

Consideration has also already been given to cooling the generator with water and to then cooling the heated water back down with a heat exchanger. All of these known solutions have in common a large amount of air that is always needed from the outside. This is particularly disadvantageous if the outside air is humid or, particularly in coastal regions, if it has a high salt content, and the cooling elements are then exposed to this humid and high salt content air. This problem is especially extreme with wind energy facilities that stand directly on the coast or, in offshore technology, directly in salt water.

SUMMARY OF THE INVENTION

One object of the invention is to provide a cooling device for a wind energy facility which reduces its losses.

The basic concept of the invention is to provide a completely closed or in an alternative embodiment, a partially closed cooling circuit for a wind energy facility, so that no or practically no outside air has to be used for cooling. In this way, the cooling air circulates within the wind energy facility from its nacelle to the tower or to the base of the wind energy facility and the energy stored by the coolant, preferably air, during the cooling is dissipated by means of the tower of the wind energy facility. The tower of the wind energy facility is always exposed to the wind, so that the tower of the wind energy facility acts as a cooling element or a heat exchanger, which dissipates the stored energy to the wind enveloping the tower.

Another advantage of the concept according to the invention is that the tower is also heated from the inside out for very cold outside temperatures of approximately -20° to -30°C by its function as a heat exchanger and a load-bearing part of the wind energy facility. Due to this fact, the wind energy facility can remain in operation. According to the state of the art up until now, a special cold-resistant steel had to be used for very cold locations, such as, *e.g.*, northern Sweden, Norway, Finland, Canada, etc.

If desired, due to very low outside temperatures below the freezing point, it is also possible to combine the heating of the rotor blades with the cooling circuit, so that the rotor blades can be heated with the fluid in the cooling circuit.

The coolant is cooled by the tower due to the fact that at least one air channel is formed in the tower itself (inside or outside), and the heated air flows through this channel such that the air can dissipate its energy at least partially at the tower walls.

One air channel is preferably formed such that the tower is configured with double walls, so that one part of the cooling channel is formed through the load-bearing wall of the tower.

By using the tower or rotor blades of the wind energy facility, which are usually manufactured out of steel, as a cooling element or a heat exchanger, a

component that is already present and required by every wind energy facility is used for an advantageous function. Heated air flows from the generator or transformer into the steel tower at its outer wall. This outer wall has a very large surface area, *e.g.*, for a 1.5 MW facility, approximately 500 m^2, and thus offers a very large heating/cooling surface. The wind enveloping the tower continuously cools this surface.

When the blades are used as the heat exchanger, this provides rapid cooling since they present a large surface area that rotates through the wind at high speeds. The further advantage is that the rotor blades are heated, which is an advantage in ice forming conditions since it will keep the blades free of snow and ice and save the expense of providing a separate heater for the rotor blades.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Figure 1 shows the correlation between cooling power and wind speed.

Figure 2 shows the correlation between generator power and wind speed.

Figure 3 shows an embodiment of the invention with reference to a wind energy facility.

Figure 4 shows a cross section of the tower walls cut along the line A-A from Figure 3.

Figure 5 shows an alternative embodiment of the cooling circuit according to Figure 3.

Figure 6 shows an additional embodiment of a wind energy facility according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

The possible cooling power of the wind increases with rising wind speed. This correlation is shown in Figure 1. With rising wind speed, the generator power also rises, and thus, also the heat created by the generator due to power loss. The correlation between the generator power and the wind speed is shown in Figure 2. Thus, rising heat due to increased power losses can be dissipated

relatively easily because the cooling power of the tower of the wind energy facility also rises with the increasing power loss.

Figure 3 shows an embodiment of the invention with reference to a wind energy facility according to model E-66 from Enercon, which provides a generator power of 1.5 MW. Figure 3 shows a cross section of a wind energy facility 1 in with a nacelle 2 at the end of the head, which is supported by a tower 3. This tower 3 is anchored in the ground (not shown).

The nacelle 2 houses the main driving line of the wind energy facility. This main driving line comprises a rotor 4 with rotor blades 5 (only the base of which are shown for ease in illustration), as well as a generator 40 connected to the rotor. This generator 40 has a generator rotor 6 and a generator stator 7. If the rotor 4, and thus the generator rotor 6, turns, then electrical energy, *e.g.*, as alternating current (or as direct current) is generated.

The wind energy facility further has a transformer 8, and in some embodiments a rectifier 9 connected in series before this transformer 8. The rectifier 9 supplies electrical energy in the form of alternating or three-phase current to the transformer 8. The transformer 8 feeds the energy generated by the wind energy facility into a network, preferably a medium voltage network (not shown).

The tower 3 is configured in sections with double walls 13 and 14, as can be seen in Figure 3, and in each double-walled region, a cooling channel is present. In this cooling channel 11, a fan 10 is provided (several fans can also be provided), which drives the air through the cooling channels 11. A return channel 12 is also provided.

In one alternative embodiment, a cooling channel 11a runs also through the blades 5, as shown in Figure 3. This cooling channel 11a has a dual function, to cool the generator and also to heat the rotor blades. In those environments where snow or ice build up on rotor blades and may prevent efficient operation, use of the already present and locally generated heat to provide the deicing is much more economical since heaters may not need to be installed for deicing on the rotor blades. Also, the rotor blades provide a broad, exposed surface area for raid cooling and dissipation of large amounts of heat. The cooling channels 11a are preferably located on those edges most susceptible to ice build up, so that a

direct heat transfer from the fluid to the part of the blade needing the heat occurs. Alternatively, one or more cooling channels 11a can be located on the broad front exposed surface of the blade for the most exposure to the large surface area in the wind.

The cooling fluid used is any accepted coolant. In a preferred embodiment, the cooling fluid is air. The air is preferably dry air that has been placed in the channels from ambient air on days of low moisture in the ambient air. Of course, the air can be made more dry by dehumidifiers if desired. Using dry or conditioned air with moisture removed will ensure that even on very cold days, no moisture from the air condenses out and freezes inside the channels 11, 12 or 11a. If particularly clean, moisture free air is desired, it can be filtered to remove all water vapor or pure nitrogen gas or other heat transfer gas can be used. A liquid, such as antifreeze can be used for the cooling fluid if desired.

Figure 4 shows a cross section of the tower walls cut along the line A-A from Figure 3. It can be seen here that in the illustrated example, two cooling channels 11, 12 are formed, and the tower is configured in a certain region with double walls. The air heated by the generator now flows through an air channel out of the machines in the nacelle 2 into the upper tower region. There, the heated air is directed to the inner side of the steel tower. As already mentioned, the steel tower is configured with double walls over a great length, *e.g.*, approximately 50-80%, with an outer wall 13 and an inner wall 14, and there it forms the cooling channel 11. Here, the inner wall 14 in the cooling channel can be made of a simple material, *e.g.*, plastic or cloth. The heated air from generator 40 must now flow along a large stretch on the inside of the steel tower 3. In this way, the tower or its steel is heated over a large surface area and the air is cooled.

In the lower region of the tower there is the rectifier 9 and the medium voltage transformer 8 (and/or additional electrical devices). These components must also be cooled. The cooled generator air is now guided first through the rectifier 9. Here, the devices of the power electronics are actively cooled. The air output from the rectifier is now further guided to the transformer 8 and also cools the transformer. Subsequently, the air rises through the second cooling channel 12 back upwards to the machine house and to the generator 40.

The cooling circuit is thus closed and it is not necessary to introduce cooled air from the outside.

For cooling all components, particularly sensitive components, the wind energy facility always uses the same air. It is a closed system, and once sealed with the proper air, is not later opened.

If necessary, air filters and additional cooling devices (*e.g.*, heat exchangers) can obviously also be mounted in the cooling channel, if desired.

The advantages of the invention consist in the fact that no high salt content or humid air comes into contact with the sensitive components, such as generators, rectifiers, and transformers. The risk of corrosion is thus drastically reduced within the machine housing and the tower. In the wind energy facility, particularly in its tower, there can be no build up of mold or fungi.

In one alternative embodiment, the cooling channel may have a valve that can be held open at all times or selectively opened. If it is desired to exchange outside air with the cooling fluid, the valves can be opened so that some or all of the cooling fluid is obtained from ambient air and is exhausted to ambient air. In some dry environments that require extra cooling, this may be preferred, such as in large desert areas from the ocean, such as Saudi Arabia, Arizona, New Mexico, and the like. The system can thus be a partially closed system in one alternative embodiment or a system that can be selectively opened and closed in yet a further embodiment.

In total, for the cooling of the entire wind energy facility, considerably less energy is required than before because (secondary) cooling power is produced from the outside of the tower by the wind.

By forming cooling channels in the rotor blades and by connecting these cooling channels to the cooling circuit according to the invention, it is also possible to introduce the air heated by the generator first into the cooling channels of the rotor blades, so that during cold periods, particularly for temperatures around the freezing point, the rotor blades can be deiced. The formation of cooling channels in a rotor blade is also known, *e.g.*, from DE 195 28 862.9.

The formation of the cooling channels in the machine housing is done through corresponding walls and air guiding devices, which direct the air such that it passes the elements, such as, *e.g.*, the generator.

If the cooling power of the tower is not sufficient, *e.g.*, on very warm days, it is also possible to use additional cooling elements, such as, *e.g.*, conventional heat exchangers, in the cooling circuit.

Figure 5 shows an alternative embodiment of the cooling circuit according to Figure 3. Here, it can be seen that the wind energy facility has two separate and independent closed cooling circuits 15, 16, which each dissipate stored heat to the tower. However, the two cooling circuits 15, 16 are separated from each other, which is different than the configuration shown in Figure 3. Here, each of the individual cooling circuits 15, 16 has a passage or a cross channel within the tower 3 at the turning point, so that the air flowing along one wall of the tower is directed to the opposite side of the tower and thus is further cooled for the unit to be cooled, which can be the generator 40 or the power electronics of the transformer 8, rectifier 9 and other electronics. The fluids in each circuit can be different from each other. The fluid in top circuit 16 can be air, while fluid in the bottom circuit 15 can be oil, for example.

Figure 6 shows an additional embodiment of a wind energy facility according to the invention. Here, an air channel, *e.g.*, an exhaust tube 17, leads through the interior of the lower tower section. It can extend along only part or nearly all the length of tower 3. This can also be retrofitted very easily, *e.g.*, to an existing wind energy facility and mounted or suspended in the tower 3. Heated air originating from a power box 18, *e.g.*, 600 kW power box having a transformer and rectifier therein, is guided upwards from the tower base through this exhaust tube 17 and is output from the exhaust tube 17 into the tower. From there, the heated air flows back downwards after cooling at the tower walls and there it can be suctioned again by a ventilation device 20 (for supply air), which is coupled by means of an air hood 19 to the power box 18. The exhaust tube 17 can be connected directly at the air outlet of the power box 18 or there can be a second ventilation device 21, which suctions the heated air of the power box 18 and blows it into the exhaust tube 17, at the input of the exhaust tube 17. The exhaust tube is preferably made out of

plastic and thus it is very easily realized and has a very small weight, which simplifies its attachment and retrofitting to a wind energy facility. In one embodiment, the tower 3 of Figure 6 is a hollow tube that is generally closed and may be sealed. The exhaust tube 12 is placed, with the ventilation device 20 into the interior of the tube. Air is circulated through the interior of the tower to provide cooling of the power box 18 and/or nacelle 2 having a generator therein. The exhaust tube 17 and ventilation device 20 can also be placed at the base of the nacelle and blow air downward into the tower 3. In this embodiment, the same air is repeatedly circulated to cool the various components and at the same time provide some heating of the tower as the heat is transferred. This is a closed system, or could be termed a partially closed system.

In an alternative embodiment, the tower 3 has no interior chamber but is rather in the form of steel beams, such as I beam, twin I beams, or the like. In this embodiment the exhaust tube 17 is placed along side the metal structure so that air exiting enters the open air adjacent the structure and is cooled by the ambient air and steel tower. New ambient air enters the intake of the ventilation device 20. Such a system could also be retrofit to the generator 40 in the nacelle 2 if desired. The system of Figure 6 can be thus a partially closed system in which outside air is obtained, placed in a closed system and circulated in a closed system for distance before it is released to open air.

For improving the cooling effect of the nacelle 2, the nacelle can be completely or partially made out of metal, preferably aluminum, in order to also take advantage of the cooling effect of the nacelle, which is constantly enveloped by wind, and thus to increase the generator cooling. Here, it can also be advantageous to equip the nacelle on the inside with a surface area increasing structure, *e.g.*, cooling ribs.

As first tests show, the configuration of a closed cooling circuit with the use of the air channel shown in Figure 6 is extremely effective and particularly cost effective, because the investment necessary for developing an air channel, particularly a plastic exhaust tube, is only very small in comparison with a heat exchanger and its constant maintenance costs. In addition, the cooling is extremely effective.